RAMAN IMAGING OF A GRANITIC LUNAR BRECCIA. Stephen M. Seddio, Alian Wang, Bradley L. Jolliff, Randy L. Korotev. Department of Earth and Planetary Sciences and McDonnell Center for the Space Sciences, Washington University, St. Louis, Missouri 63130 (sseddio@levee.wustl.edu).

Introduction and motivation: A variety of imaging techniques are available for the characterization of lunar samples. Molecular maps can be generated using Raman spectroscopy and are useful for distinguishing between polymorphs (e.g., quartz and cristobalite [1]). Elemental maps can be generated using an electron microprobe.

The primary motivation for this study is to determine the silica polymorph(s) present in sample 12001,909-14. Silica polymorphs are readily distinguishable by peak position. K-feldspar polymorphs can also be determined by Raman imaging. K-feldspar Raman peak positions do not change between polymorphs; instead, peak widths become wider with increasing Si-Al disorder [2]. Because the determination is based on peak shape rather than peak position, a more detailed Raman analysis is required relative to the identification of a silica polymorph.

Another motivation is to compare the information content of the LRS imaging with that obtained by the more conventional X-ray imaging. Lastly, Raman imaging requires less sample preparation than X-ray mapping because it does not require a perfectly flat surface or a carbon coat.

Methods: We characterized Apollo 12 granitic breccia 12001,909-14 [1,3] using backscattered electron (BSE) imaging, X-ray maps, and Raman imaging. BSE images and X-ray maps were made using a JEOL 8200 electron probe. We obtained X-ray maps using a 1 µm probe diameter, a 15 kV accelerating voltage, a 50 nA current, and an 8 msec dwell time.
Molecular maps were made using an inVia® Raman System (Renishaw). The Raman signal was stimulated using 532-nm line of a diode pumped solid state laser, and a Streamline™ mode was used to collect a Raman imaging data cube. Raman analysis was done using a

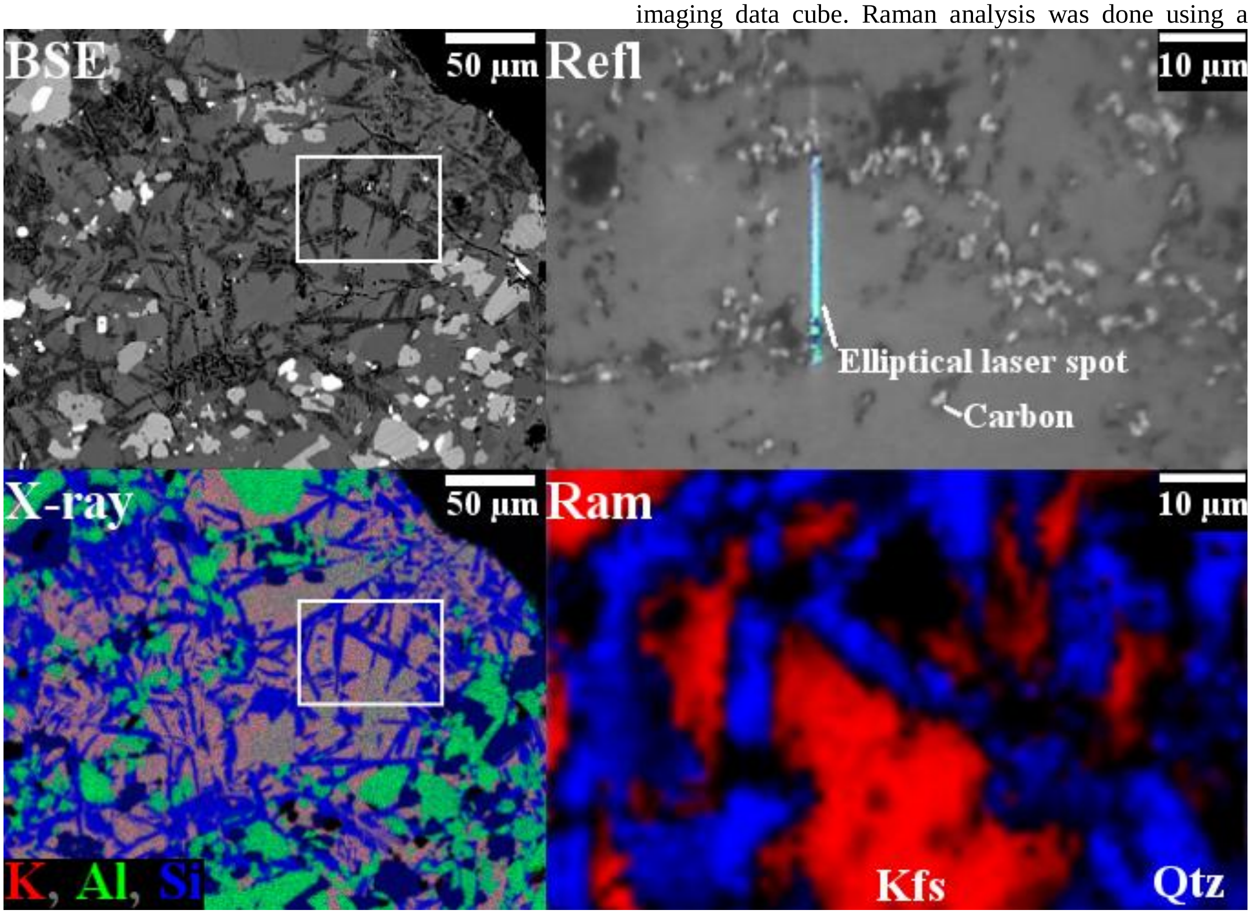
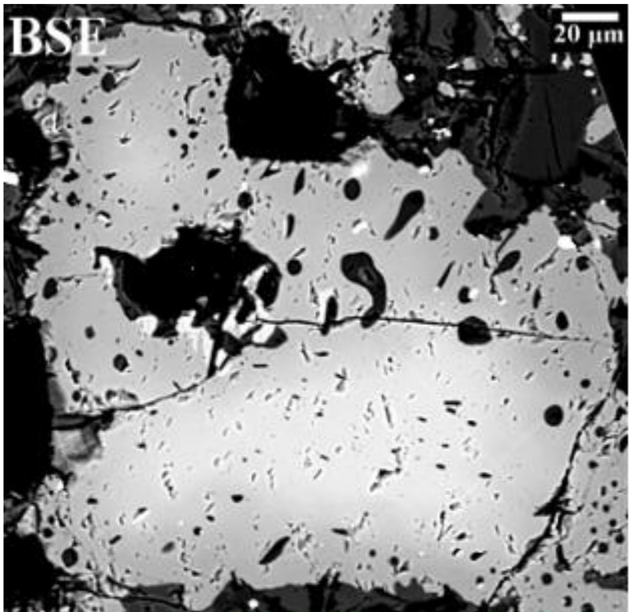


Fig. 1. BSE: Backscattered electron image of granophyre in 12001,909-14. White rectangle (also in "X-ray") indicates the area of the reflected light and Raman images. **X-ray:** X-ray maps of K, Al, and Si in 12001,909-14 as an RGB image; quartz is blue, K-feldspar is pink, plagioclase is teal. **Refl:** Reflected light image of the area as Raman image cube. The 532-nm, green laser spot with elliptic shape in Streamline™ mode is visible. Bright specks are carbon trapped in fractures. **Ram:** Raman image of the highlighted area in "BSE" and "X-ray." Red areas have spectra that match the Raman spectrum of K-feldspar. Blue areas match the Raman spectrum of quartz. Black areas have spectra that do not match the quartz or K-feldspar or there are no Raman peaks (holes or fractures).



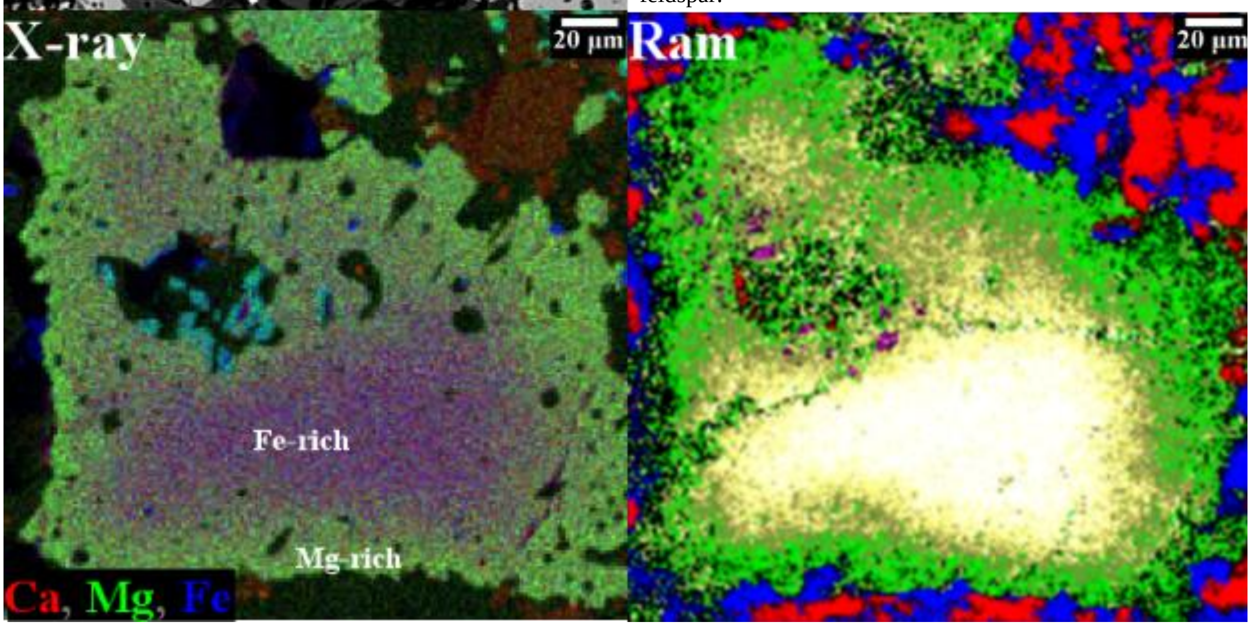


Fig. 2. Images of a zoned clinopyroxene grain in the granitic matrix of 12001,909-14 [3]. The core has a composition of $En_{10}Wo_{41}Fs_{49}$; the rim has a composition of $En_{34}Wo_{39}Fs_{27}$. **BSE:** Backscattered electron image. Zoning evidenced by brighter core and darker rim. **X-ray:** X-ray map of Ca, Mg, and Fe in 12001,909-14 as RGB image. Teal is low-Ca pyroxene—a reaction product of fayalite with surrounding quartz and the magnesian lithology. Fayalite occurs with quartz and K-feldspar in an inclusion that crystallized from late-stage melt. Inclusions of fayalite+K-feldspar+quartz also occur in hedenbergite in lunar granite 12032,366-19 [3]. Blue specks are ilmenite. Teardrop-shaped inclusion is K+Si glass surrounding Ca-phosphate (red speck). **Ram:** Raman image in which white, yellow, and green represent pyroxene: white-yellow tones represent areas with spectra most like hedenbergite; green-gray tones represent areas with spectra most like diopside. Red areas have spectra that match K-feldspar. Blue areas have spectra matching quartz. Magenta areas have spectra matching orthopyroxene (low-Ca pyroxene in “X-ray”). Black areas have spectra with no Raman peaks (holes or fractures) or spectra that do not match pyroxene, quartz, or K-feldspar.

50× long-working distance objective (NA=0.5), which condenses the laser beam into an elliptical spot of 1 µm × 30 µm to irradiate the sample (Fig. 1) and also collects the back-scattered Raman photons from the sample. A 1.3 µm step size was used to collect the Raman image cube in this study. More details on the laser-Raman imaging methods can be found in [4].

Results: 12001,909-14 is a breccia composed of clasts of granite, basalt, and mineral fragments in a granitic matrix. The matrix (Fig. 1) is composed of granophyric intergrowths of K-feldspar and quartz. Fig. 2 depicts a pyroxene grain in the granitic matrix. The grain has a hedenbergite core and an $En_{34}Wo_{39}Fs_{27}$ rim. This zoning indicates that the pyroxene grain formed in a granite and then equilibrated with the more magnesian basaltic clasts upon incorporation into the breccia [3].

Raman imaging and X-ray mapping can produce images of similar resolution in similar amounts of time; however, Raman imaging requires significantly less sample preparation. The techniques produce similar (e.g., the zoning in Fig. 2) and complementary results (e.g., X-ray mapping reveals differences in trace element concentrations, and Raman imaging can distinguish between polymorphs).

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References: [1] Seddio et al. (2013) This conf. [2] Freeman et al. (2008) *Can. Min.*, 46, 1477-1500. [3] Seddio et al. (2012) *LPSC43*, Abstract #1006. [4] Du and Wang (2012) *LPSC43*, Abstract #2221.